

Jharia mine fire with special reference to mining at Chasnalla quarry

Coal is the main source of fuel in India and most of India's prime coking coal comes from Jharia coal belt. But in Jharia numerous coal seams are affected by mine fire, the main cause of which is spontaneous combustion. Mining factors such as selective mining of superior quality coal seams at shallow depth, poor soil cover, poor coal recovery during exploitation etc are also responsible for Jharia coal mine fire. This paper deals with status of Jharia coal mine fire and methods to combat those fires with a few case studies. Mining at the fire area of Chasnalla western quarry are discussed in detail. How heating can be prevented with safe mining practices is also outlined. Intrinsic and extrinsic properties of coal causing spontaneous combustion are also mentioned.

Introduction

Coal-mine fires are a national problem in India. They are not only hazardous to the workers employed in the mines but they also result in heavy losses of coal that is valuable as a national asset and is the country's primary source of energy. Other than loss to property and monetary loss mine fires threaten the stability of surface structures also. Prior to the nationalization of the coal mining industry in 1972-73, implementation of control measures was constrained by a lack of resources. In the post-nationalization era preventing and combating mine fires (both underground and surface) is a national priority.

In this paper an attempt has been made to discuss the status of Jharia coal mine fire and methods to combat those fires with a few case studies. Further, mining at the fire area of Chasnalla western quarry are also enumerated.

Spontaneous combustion

Spontaneous heating is one of the main causes of mine fires as approximately 70% of mine fires in India are due to spontaneous heating. Once fire has occurred in a coal seam or block it is very difficult to control and leads to safety and environmental hazard. Spontaneous heating requires three main ingredients for its occurrence (Banerjee, 1985):

- ♦ Fuel – coal having specific physico-chemical properties, mass and geometrical shape
- ♦ Supply of oxygen at specific concentration and flow
- ♦ Adequate condition for heat accumulation

Intrinsic and extrinsic factors responsible for spontaneous combustion of coal are given in Table 1 (Kaymakci and Didari, 2002).

PREVENTION OF SPONTANEOUS HEATING

Spontaneous heating on coal may be prevented by application of suitable measures in working mines. The preventive measures like early detection; ventilation parameter and air leakage and mining parameters should be taken care of.

Early detection

Early and reliable detection of heating is necessary in a mine to avoid coal mine fire. In the present day practice goaf stink, appearance of haze and increasing value of CO/O₂ deficiency ratio (Graham's ratio) are normally used for detection of onset of incipient or active heating. Other gas indices, which are useful for knowing the status of fire, are Willett's ratio, CO/O₂ ratio, Jones and Trickett ratio and C/H ratio (Ray et al., 2004 and Singh et al., 2007). Many researchers (Bhowmick and Dhar, 1995; Kiyoshi and Kotaro, 1997) have advocated for improved system in the following direction:

- ♦ Use of infrared sensors for detection of hot spots in pillar, stopping, airway etc.
- ♦ Continuous monitoring of CO in return and other segments of mine airway
- ♦ Smell sensors to be placed in potential zone for maximum effect

Environmental telemonitoring system suitable for underground coal mines have also proved advantageous all over the world for early detection of heating.

Ventilation parameter and air leakage

The ventilation pressure difference should not be too high to initiate leakages through coal pillars lying between intake and return airways. In fact, where main intake and returns are too close the ventilation pressure difference

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TABLE 1: CAUSES OF SPONTANEOUS COMBUSTION

Intrinsic factors (nature of coal)	Extrinsic factors (atmospheric, geological and mining conditions)
• Pyrites	• Temperature
• Moisture	• Moisture
• Rank and petrographic constituents	• Barometric pressure
• Particle size and surface area	• Oxygen concentration
• Chemical constituents	• Coal seam and surrounding strata
	• Method of working

should be reduced to a minimum. High ventilating pressure of fan causes leakages from goaves. Airflow rate of 0.1 to 0.9 m/min. with O₂ percentage more than 17 is considered risky zone of ventilation (Banerjee, 1985).

Leakage of air through ventilation stoppings/isolation stoppings provides oxygen through cracks and fissures in coal pillars which may lead to spontaneous heating. CIMFR has developed sealants to minimize leakage through stoppings as well as coal pillars so that possibility of heating in coal pillars can be minimized.

Mining parameters

The panel system is an appropriate method for mining seams liable to spontaneous heating as it facilitates complete extraction within the incubation period and effective sealing is possible with a few stoppings. Seams with cracks and cleats, and high friability would cause spontaneous heating because of the availability of more surface area.

Fire at Jharia coalfield

The need to contain and control the fires in Jharia can hardly be overemphasized because this coalfield is the only source of prime coking coal in the country. History of fire at Jharia coalfield dates back to 1916 when the first incidence of fire was reported from XIV seam of Bhowrah colliery. Since then a number of fires have occurred in underground workings, in opencast pits and in opencast overburden debris. According to the investigations made after nationalization 70 fires were known to exist in JCF in the leasehold of BCCL, covering an area of 17.32 sq.km. 7 additional fires identified after nationalization. Fig.1 indicates Jharia coalfield and its principal collieries that are affected by fires.

Fires in the Jharia coalfield have resulted in colossal loss of the country's meager coking coal reserves. About 37 million tonnes of prime coking coal has already been lost. Another 1453 million tonnes is inaccessible because of flooding or sealing of underground workings due to fire

In addition to the enormous direct losses, there are various other problems and danger associated with the Jharia fires such as production outlets are in imminent danger of being engulfed by fires, vital and costly surface structures and installations, such as the washery, the by-product plants, the beehive coke plant, and a ropeway that is the main production link between a washery and a prime coking coal unit, are in danger, the important railway lines and roads are being threatened.

CONTROLLING AND CONTAINING MINE FIRE AT JHARIA

At the time of nationalization there were 70 fires in Jharia.

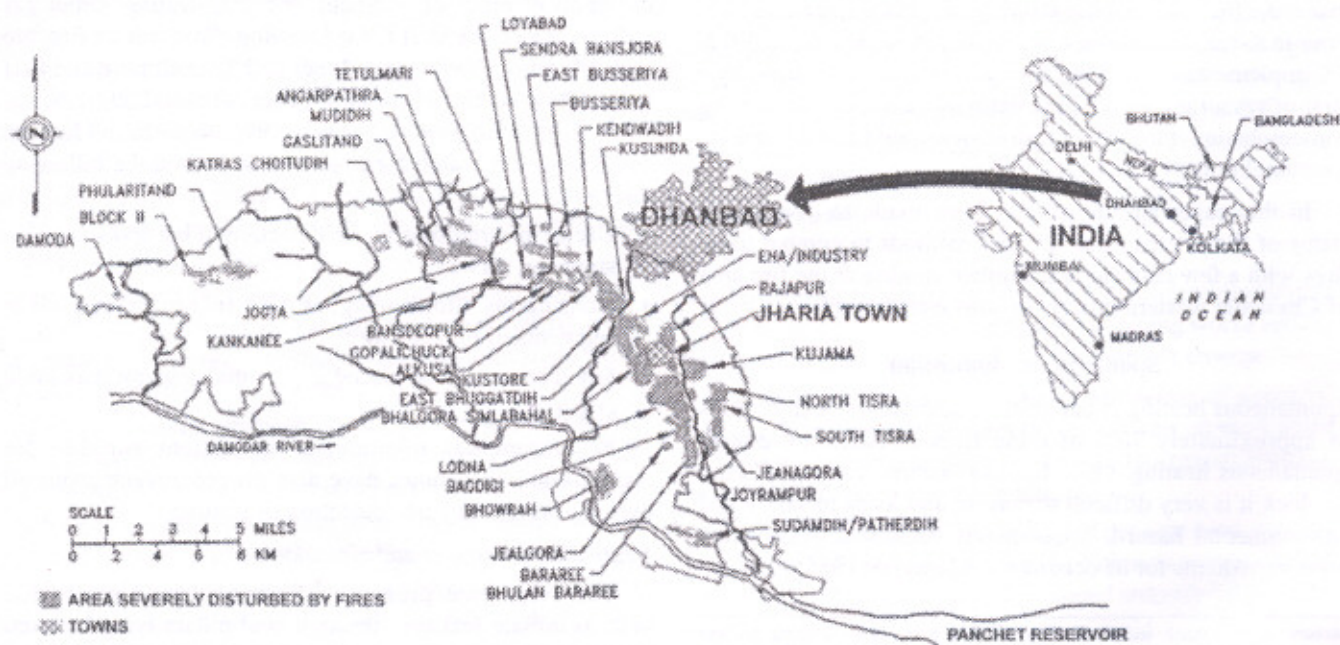


Fig.1 Jharia coalfield and principal collieries affected by underground mine fires (Michalski, 2004)

TABLE 2: ADMINISTRATIVE AREA WISE NUMBER OF FIRES IN BCCL IN JHARIA

Area	Total number of fires		Total
	Actions required	Action not required (except maintenance)	
1 Barora	5	-	5
2 Block -II	1	-	1
3 Western Jharia	-	-	-
4 Govindpur	-	-	-
5 Katras	4	-	4
6 Sijua	9	2	11
7 Kusunda	7	-	7
8 Pootkee-Balihari	4	2	6
9 Kustore	9	3	12
10 Bastacolla	2	-	2
11 Lodna	13	1	14
12 Eastern Jharia	4	1	5
Total	58	9	67

Out of 70 fires, 59 fires were dealt with by BCCL during 1976-1988 by making 22 fire projects. The best available technology, such as surface sealing, digging, trenching, inert gas infusion and sand-bentonite mixture flushing etc. was tried to deal the fire.

The implementation of various projects have resulted in more than 50 million tonnes of sand stowed below ground, over 22 million cubic metre of blanketing work, 3 million m³ of nitrogen flushing and a sum of Rs.76 crores have already been spent in the fire fighting till march 1997 (Michalski, 2004).

The projects use two types of measures to combat the fires: measures to contain the fires to their existing limits as far as practicable, and measures to extinguish the fires. Efforts to extinguish the fires have been partially successful. About 67 fires affecting 41 mines continue to burn in the coalfield as of 2008.

The following are list of mine/seam fires which have been controlled/extinguished as reported.

Angarpathra XII, XI, X special seam (UG Fire), Pootkee XV seam (UG fire), Kessurgarh V/VI/VII seam (surface fire), Jogidih X seam (surface fire), Kooridih X seam (surface fire), East Katras XIV seam (surface fire), West Munidih IX/X seam (surface fire), Nudhkhurkee X seam (surface fire), Moonidih XVII T seam (UG fire), Sudamdih XV seam (UG fire).

A fire is contained or isolated by one or a combination of the following operations:

Conventional methods

It includes methods such as isolation by trenching, blind flushing, surface sealing/remote sealing of mine gallery, isolation by underground stopping, cooling by water, direct attack with chemicals, rock dust or sand etc.

Other methods

It includes methods such as inert gas injection (liquid nitrogen or CO₂), chemical treatment, modified bulk filling (water/slurry), dynamic balancing of pressure, injection of high pressure high stability (HPHS) nitrogen foam, reversal of underground mine ventilation, inertisation of goaf in operating panels etc.

Fig.2 indicates isolation of fire by trench cutting at Sendra Bansjora colliery, BCCL whereas Fig.3 shows blanketing with soil over coal fire at Rajapur colliery, BCCL. Fig.4 shows digging out fire below Dhanbad-Patherdih railway line at Bararee colliery, BCCL whereas Fig.5 illustrates injection of HPHS nitrogen foam at Lodna colliery, BCCL. Fig.6 shows water-spraying arrangement in one of BCCL mines.

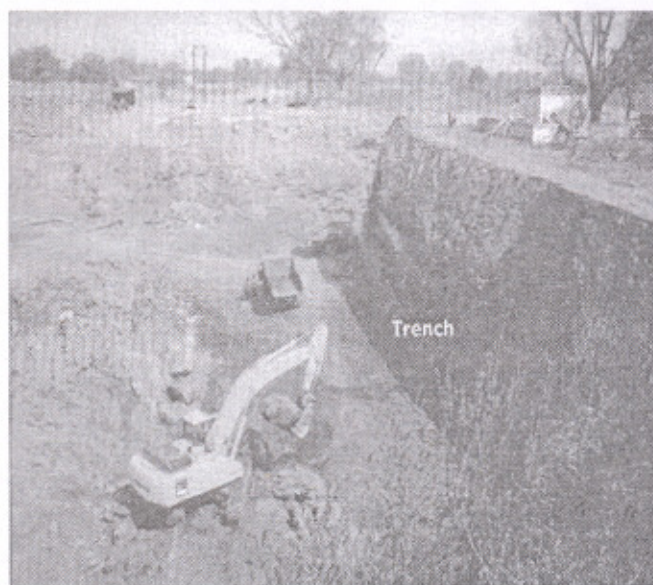


Fig.2 Isolation by trench cutting

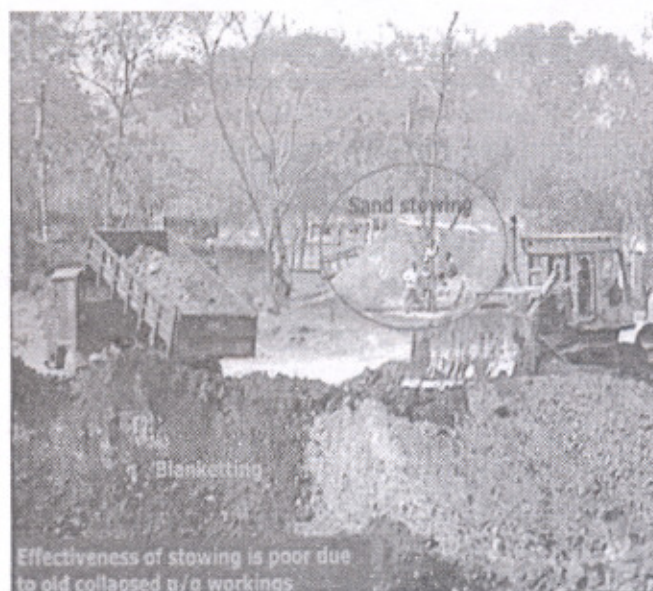


Fig.3 Blanketing with soil



Fig.4 Digging out fire



Fig.5 Injection of HPHS nitrogen foam

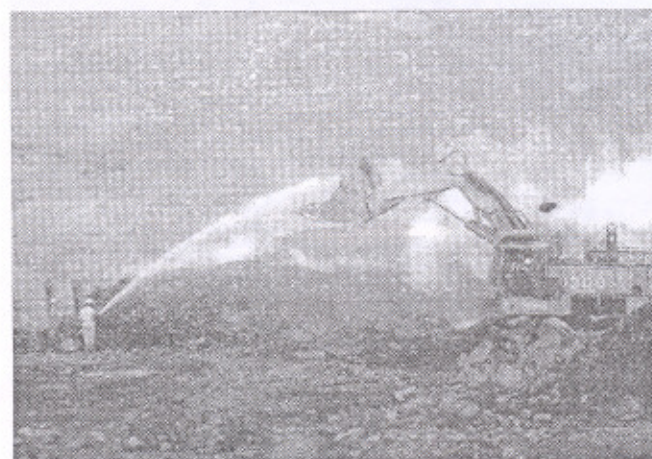


Fig.6 Water spraying arrangement

The implementation of these schemes, though could not extinguish all the fires completely, it was possible to achieve the following. These measures controlled majority of the fires from total devastation. It reduced the total surface area affected by fire to 8.9 sq.km from earlier reported 17.32 sq.km. and also reduced the blockage of coal from 1864 Mt to 1453 Mt (GAI/METCHEM, 1996). However, slow fire activities continue.

CASE STUDIES

The following case studies show how mine fire has been combated in different mines of Jharia coalfield.

Jogta mines

The first fire in Jogta was detected in 1941 in a depillaring district of seams XIII and XIV in a panel located in the southeastern sector of the mine. The cause of the fire was crushing and premature collapse of the pillars (due to high workings, inadequate pillar size, and lack of superimposition) and spontaneous heating. The panel was sealed by stoppings and the depillaring operation was shifted to the west panel.

Considering that the depth of the workings was low and varied between 20 and 70m, protective measures were taken to build up the areas located on the rise side of the west panel, which consisted of manual packing with alluvium below the built-up areas, blanketing the surface over the workings of the south-west panel, stowing sand through boreholes on the east to prevent movement of the fire across the seasonal river on the east, and cutting a trench south of the railway line to isolate the Sijua railway station and its complex.

After the ineffectiveness of these measures to contain the fire methods suggested by Central Mine Planning and Design Institute, Ltd were implemented since 1980. Both eastern and western sides of the mine were blanketed but the blanketing in the western side was thicker. As expected, when dumping of material and blanketing progressed at one end, the fire tended to move away from that area. To ensure that by blanketing the east the fire was not driven toward the west, or vice versa, it was decided to blanket 100 m wide strips alternately located on the eastern and western ends to contain the fire in the center (Sinha, 1986).

Laikdih deep colliery

At Laikdih deep colliery, the selective method of mining and friable nature of coal has resulted in numerous fires occurring. A fire, which originated in the 1950s, was advancing towards access shafts, requiring regular shifting of a row of stoppings, thus sterilizing more and more coal. In 1981, the row of stoppings was again threatened, but no further retreat was possible. The sealing of fires had been ineffective due to multi-section working and weak parting of coal that allows inflow of fresh air. Superimposition of stoppings in different sections and cement injection around stoppings has also not helped. Frequently the fire jumped over stoppings. Due to the fact that the fire had not been

properly isolated, the decision was taken to install an N_2 generating plant at the colliery. The plant, with a capacity of 500 m³/hr, was commissioned in March 1981. The gas was fed through stoppings via the mine pump delivery system. The oxygen concentration was reduced 5% to 0.57% over a two-month period (Garg, 1987). Temperature of stoppings also came down to normal. CO content in the samples at most of the stoppings was no more than a trace. One million m³ of N_2 gas was pumped in over the period, with average running time of the plant being 2 hrs per day. With continued injection of N_2 gas, the fire remained dormant, the only requirement being the injection of water through sprays to lower the temperature. This whole exercise was only partially successful because of heavy air leakage in this section of the mine.

Lodna colliery

In Lodna colliery, an underground fire was advancing to beneath an office building, washery, coke oven plant and railway line. A trench was dug to stop the fire and protect the office complex. The fire was initially fought with liquid N_2 transported to the mine. It was fed through a bank of vapourizers and into the mine through boreholes. Subsequently, a PSA type N_2 generator, with a capacity of 500 m³/hr, was installed at the mine. In 1985-86, Indian Oxygen Limited installed an evaporation plant at this colliery and fed a total quantity of 94,000 m³ of N_2 into the mine, spread over a period of about 8 months. This N_2 injection had a positive effect on the fire (Garg, 1987).

Moonidih colliery

Spontaneous heating in F1 longwall caving panel of XVI combined seam was detected in August 1993 in Moonidih Colliery (BCCL), a degree III gassy mine. Nitrogen flushing proved successful in controlling the fire and helped in salvaging the longwall equipment.

Sijua colliery

The fire in XIII and XIV seams of Sijua colliery, TISCO was sealed off and after continuing for several years, was brought under control by pressure balancing. In order to meet production target and provide adequate ventilation at various working faces, mine management installed a higher capacity fan (VF-3000) at pit No. 8 and made several changes in the ventilation network of the mine. These changes resulted in pressure imbalance across the fire-affected zones in XIII and XIV seams, leading to deterioration of condition of the fire.

CIMFR, Dhanbad (erstwhile CMRI), after detailed investigation and computerized planning, advised the management of mines to opt for dynamic balancing of pressure for some portions of the mine and recommended procurement, installation and commissioning of a 500 m³/hr. capacity N_2 gas generator (PSA type) for fire control purposes.

Measures to implement and adopt dynamic balancing of pressure yielded encouraging results. The fire was brought under control in most parts of the mine. However, at a few

places in the sealed-off area, O_2 concentration did not fall to the desired level. This was attributed to existence of an air leakage path extending beyond the pressure balancing zones. For further improvement in the condition of the mine it was suggested to install a second nitrogen generator in the mine having a capacity of 500 m³/hr. This will assist in maintaining uninterrupted supply of nitrogen during any breakdown or maintenance of one of the units (Ray et al., 2000). The mine at present is producing 1050 TPD of coal maintaining pressure balancing for fire area and infusion of nitrogen generated through nitrogen generator.

Surface mining in fire zone at Chasnalla colliery, Jharia

Chasnalla colliery, owned by ISP, SAIL, is located in the eastern part of the Jharia coalfield. The colliery has a mineable reserve of over 40 Mt of high grade prime coking coal. The colliery lies between latitudes 23° 40' 03" N and 23° 38' 33" N and longitudes 86° 26' 52" E and 86° 27' 57" E and has a leasehold area of 345.31 ha. The general strike of the coal bearing strata is N 62° W - S 62° E. The dip of the strata ranges from 25° to 60° towards south and southwest.

Chasnalla colliery is being worked through both opencast and underground mining method. Opencast mining is being carried out in two sections namely, eastern and western quarries. The colliery is also equipped with a washery. Clean coal and middlings are dispatched from Chasnalla washery to the IISCO and SAIL plants by rail from the Tasra siding, which is about 3 km from the washery. Mining is in progress in western quarry

WESTERN QUARRY

Presently multi seam surface mining is going on in western quarry where IX/X, XII, XIII/XIV, XIVA and XV seams are being worked. Surface mining is done by developing benches of height 9 m having haul road width of 12 m. The overall stripping ratio for this part of the mine is 1:5. The ash percentage of the coal is 21% to 35%. The composition of overburden is mainly sandstone and shale. The machines used for mining are front-end loader for excavation, drilling machine (150 mm dia), dump truck (40 t capacity) of L&T. The average production for this quarry is 135000t/year out of which amount of coal production is 25000t/year.

The machines used are L&T make excavators, BEML make dumper and bull dozer and drilling machine of Atlas Copco make.

FIRE AREA

Western quarry is being plagued by fire in XIII/XIV combined seam, the cause of which is spontaneous combustion of the abandoned old workings. The seam is 19 to 25 m thick that dips generally at 35° to 42° with local variations. These seams are combined near the outcrop region where it is extensively mined by quarry and inclines. It may be mentioned here that XIII/XIV seam was developed in the underground in the past at J, K, L and L (old) levels.

In spite of the presence of the fire, excavations from these seams are carried out through directly attacking the fire and then taking out coal from the fire affected area. The method of tackling fire is indigenous to this mine. Blanketing is done by spreading sand over exposed coal to cut out oxygen supply (to break the fire triangle) and then water is sprayed over it to completely extinguish it. After this the temperature of the burnt coal is measured and if it is found to be greater than 80° then it is left there for further treatment. Otherwise after sprinkling water, coal is excavated from fire area by digging it out with the front-end loader.

If the dugout coal is found to be reddish in colour, which implies that the coal is completely burnt, then it is not transported anymore and dumped near the pit top. Sand used for blanketing is taken from the top bench (which is deposited in the mine area by tributaries of Damodar long ago, which has since then dried up). So there is no cost of transporting this sand and as it is available in plenty, account of sand used is not kept. Sand from top bench is transported to the face with the help of the 35t dumpers.

Two tankers of water is used up every day for this purpose, with each tank capacity is 28000 l. Source of water is underground water. Water barriers are put up to prevent the fire from spreading underground. The water spraying arrangement is fitted to the dumper where the motor and centrifugal pumps are coupled together. Centrifugal pump delivers water at 600 l/min @ 70 m head or 1200 l/min @ 50m head. The diameter of the hose through which water is sprayed is 4 in. The machine has got a self filling arrangement to suck water from any low lying water body if necessary. The pressure jet is delivered through a fish tail nozzle.

Blasting at fire area

Before blasting, temperature is measured at a regular interval. If temperature of the face is more than 18°C then it is cooled by water until it comes down. When the temperature comes down below 18°C then charging and blasting is done as quickly as possible (preferably within 2 hrs).

If not much heat is present at the face then dry sand is put at the bottom of the drill hole and also at the top for stemming. Blasting is necessary in the fire area for blasting overburden (shale).

Problems and precautions

Underground development working of XIII/XIV seam is in close proximity to its opencast face. Therefore, while taking out coal from fire area of opencast face an excavator often encounters underground worked out workings or galleries. To avoid this, before digging out coal, the machine bucket of the excavator is dipped into the face with full machine weight to check whether it goes in completely or whether there is any solid ground to support excavation. If at all any gallery is encountered then it is filled up with debris and compacted and then excavation is done.

The workers associated with excavating coal from fire area do not wear any special protective cloth as they are exposed

to the fire for a very short period of time and only comply with the general safety features.

The coal is too much friable to be stacked and as Chasnalla has its own washery very nearby so the excavated coal is taken directly to the washery by the truck. Presently investigation is carried out to check whether infusion of silicon in the coal seam can decrease its temperature.

Conclusion

If the method applied at Chasnalla colliery is applied to other surface fires raging in Jharia coalfield and successfully replicate their direct attack method in digging out coal, then the amount of coal loss due to fire can be considerably lessened. Latest reports reveal that there have been improvement in fire scenario at Jharia, but still there are lots of projects waiting to be implemented which can contain Jharia mine fire very effectively, otherwise the coal loss due to this hazard can be enormous for energy deficient country like India.

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